LOW TEMPERATURE PLASMA ASSISTED InP-TO-SILICON WAFER BONDING: AN ALTERNATIVE TO HETEROEPITAXIAL GROWTH

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The integration of dissimilar materials is a key issue in design and fabrication of future devices. Also, in today's fast growing III-V industry the need for larger substrates becomes crucial for higher efficiency in high-volume production. For InP the development of large area substrates has not been able to keep up with market demands. One way to circumvent this problem is to use silicon substrates that are large-area, low-cost, and mechanically strong with high thermal conductivity. In addition, silicon is transparent at the emission wave-lengths most often used in InP-based optoelectronics. Unfortunately, the large lattice-mismatch, 8.1%, between silicon and InP, has limited the success of heteroepitaxial growth. In this study we therefore present InP-to-Si direct wafer bonding.

Wafer bonding enables a completely new freedom in the design of components and systems, e.g. for high performance optoelectronic integrated circuits (OEIC). Although it has proved to be a useful and versatile tool, the high temperature annealing that has been needed to achieve reliable properties sometimes hampers its applicability. We have recently shown that high temperature annealing induces severe material degradation. Therefore, low temperature wafer bonding procedures may further qualify this technology.

In this work, low temperature wafer bonding procedures using oxygen plasma surface activation have been studied. A specially designed fixture was adopted enabling *in situ* oxygen plasma wafer bonding. Here, the optimisation of the plasma parameters was shown to be the key to improved results: To optimise the InP-to-Si wafer bonding, several surface pre-treatments have been evaluated. The surfaces were examined using AFM and XPS. The bonded interfaces were evaluated using IR-transmission, bond-strength, and current-voltage measurements. Hydrophilic surface treatment using oxygen plasma with correct plasma parameters makes room temperature InP-to-Si bonding very spontaneous, and results in high bond-strengths already after low-temperature annealing. However, the oxygen plasma creates thin surface oxides that increase the resistance of the bonded junctions.

Alas, oxygen plasma assisted wafer bonding reliable InP-to-Si integration was achieved already at low temperature, thereby circumventing the problems associated with the lattice and thermal mismatch that exist between these materials. As a result, low temperature InP-based epitaxial layer transferring to Si is presented and exemplified with working diodes. Finally, we will show high-quality SiO_2 insulator layers on InP realised at low temperatures with an equivalent process scheme.

It is concluded that low temperature oxygen plasma assisted wafer bonding is an interesting approach to integrate dissimilar materials, for a wide range of applications.

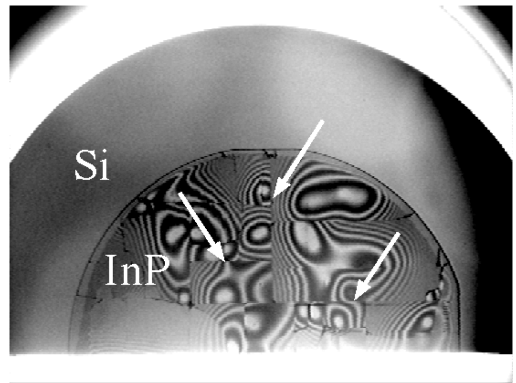

Fig. 1. IR-transmission image of InP-to-Si wafer bonding after annealing at 570 °C. Cracks in InP wafer are clearly seen whereas the Si wafer remains intact.

a)

b)

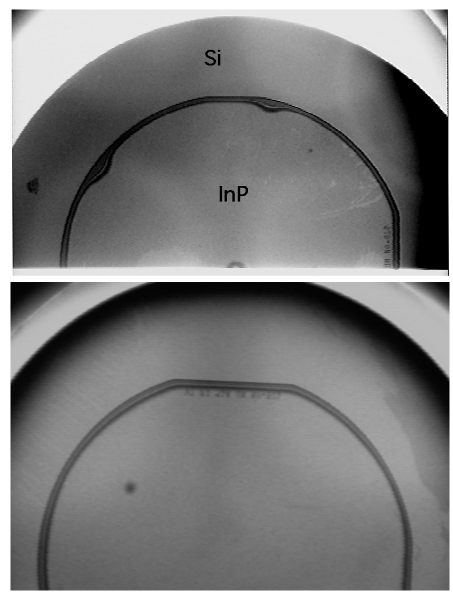

Fig. 2. Infrared transmission images of a room temperature bonded InP and silicon wafer pair after oxygen plasma assisted wafer bonding *in situ* the reactor (a), and after annealing at 200 °C.

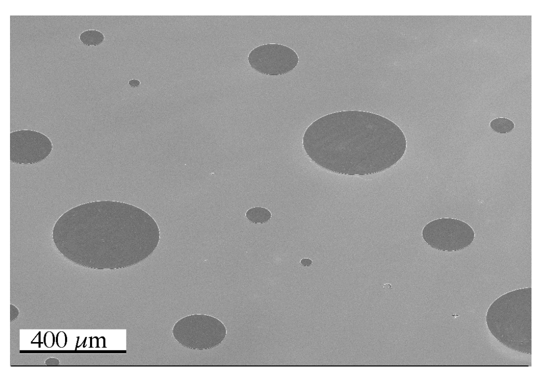

Fig. 3. Dry etched diode InP based LED mesas on a Si wafer.